

The Subjective Health Horizon Questionnaire (SHH-Q): Assessing Future Time Perspectives for Facets of an Active Lifestyle

Sandra Düzel^a Manuel C. Voelkle^{a, d} Emrah Düzel^{b, c} Denis Gerstorff^d
Johanna Drewelies^d Elisabeth Steinhagen-Thiessen^e Ilja Demuth^{e, f}
Ulman Lindenberger^{a, g}

^aMax Planck Institute for Human Development, Berlin, ^bInstitute of Cognitive Neurology and Dementia Research, and ^cGerman Center for Neurodegenerative Diseases (DZNE), Magdeburg, ^dHumboldt-Universität zu Berlin, Berlin, ^eResearch Group on Geriatrics, and ^fInstitute of Medical and Human Genetics, Charité – Universitätsmedizin Berlin, Berlin, Germany; ^gEuropean University Institute, San Domenico di Fiesole, Italy

Key Words

Successful aging · Novelty-oriented motivation ·
Exploration · Subjective health horizon · Healthy lifestyle

Abstract

Background: A wider subjective time horizon is assumed to be positively associated with longevity and vitality. In particular, a lifestyle with exposure to novel and varied information is considered beneficial for healthy cognitive aging. At present, measures that specifically assess individuals' perceived temporal extension to engage in active lifestyles in the future are not available. **Objectives:** We introduce and validate a new self-report measure, the Subjective Health Horizon Questionnaire (SHH-Q). The SHH-Q assesses individuals' future time perspectives in relation to four interrelated but distinct lifestyle dimensions: (1) novelty-oriented exploration (Novelty), (2) bodily fitness (Body), (3) work goals (Work), and (4) goals in life (Life Goals). The present study aims at: (a) validating the hypothesized factor structure of the SHH-Q, according to which the SHH-Q consists of four interrelated but distinct subscales, and (b) test-

ing the hypothesis that the Novelty and Body subscales of the SHH-Q show positive and selective associations with markers of cognition and somatic health, respectively. **Methods:** Using structural equation modeling, we analyzed data from 1,371 healthy individuals (51% women) with a mean age of 70.1 years ($SD = 3.6$) who participated in the Berlin Aging Study II (BASE-II) and completed the SHH-Q. **Results:** As predicted, the SHH-Q formed four correlated but distinct subscales: (1) Novelty, (2) Body, (3) Work, and (4) Life Goals. Greater self-reported future novelty orientation was associated with higher current memory performance, and greater future expectations regarding bodily fitness with better current metabolic status. **Conclusion:** The SHH-Q reliably assesses individual differences in four distinct dimensions of future time perspective. Two of these dimensions, Novelty and Body, show differential associations with cognitive status and somatic health. The SHH-Q may serve as a tool to assess how different facets of future time perspective relate to somatic health, cognition, motivation, and affect, and may help to identify the socioeconomic and individual antecedents, correlates, and consequences of an active lifestyle.

© 2016 S. Karger AG, Basel

Theories of cognitive aging point to modifiable lifestyle factors that modulate cognitive trajectories from early to late adulthood [1]. Relevant experimental evidence shows that improvements in physical fitness and cognitive stimulation can ameliorate brain structure and brain function, and enhance cognitive performance in adulthood [2–5]. These experimental findings are in line with evidence from animal models indicating that physical activity with exposure to novel and varied information has beneficial effects on brain and behavior [6–9]. All these observations converge on the importance of engaging in an active and stimulating lifestyle. Hence, it is surprising that a measure asking individuals to indicate for how long they will pursue such a lifestyle in the future has not yet been developed. We postulate that individuals' self-reported temporal extension to engage in an active and stimulating lifestyle may show positive reciprocal associations with cognitive functioning, which, in part, may be mediated by their motivation to select cognitively challenging life goals. The latter claim can be derived from prominent lifespan psychological theories that address the relationship between motivational focus and future time horizons [10, 11]. In this context, prior work has used the Future Time Perspective scale (FTP) [12] to capture individuals' global perceptions of their overall time left to live. Generally, the FTP scale is considered as a unidimensional construct assessing how 'open' or 'limited' individuals' perceptions of their future are. Using the FTP, it was found that a more extended future time perspective is positively related to emotion [13], health [14], and social cognition [15, 16].

In our view, a questionnaire that assesses future time perspectives for an active and stimulating lifestyle should take into account that they may not form a unidimensional construct. For instance, individuals may distinguish between physical and cognitive aspects when judging their future time perspectives. Whereas future perspectives regarding the ability to remain physically active may be influenced to a greater extent by bodily health, the perceived ability to explore novel settings may be influenced to a greater extent by neural circuits that process novelty and support the exploration of novel environments (see [8, 17]). These circuits include brain regions involved in episodic memory (EM), most notably the medial temporal lobes and the hippocampus, including their dopaminergic projections [8, 18, 19].

In contrast, work-related perspectives and general perspectives about goals in life are more likely to be shaped by social and socioeconomic factors, and may therefore differ in their sets of correlates from perspectives related to novelty and physical health.

Based on these considerations, we developed a new self-report measure, the Subjective Health Horizon Questionnaire (SHH-Q). The SHH-Q is meant to capture individuals' future time perspectives in relation to four hypothetical dimensions: (1) novelty-oriented exploration (Novelty), (2) bodily fitness (Body), (3) work goals (Work), and (4) goals in life (Life Goals). In contrast to the FTP, the SHH-Q assesses individuals' self-reported tendency to engage in an active lifestyle in a multidimensional manner.

The present study had two main goals: first, to establish reliability and construct validity of the SHH-Q, including its hypothesized four-factor structure, we used confirmatory factor analysis (CFA), a variant of structural equation modeling (SEM; e.g. [20, 21]). Second, to check for discriminant validity, we specifically examined whether two of the subscales of the SHH-Q, Novelty and Body, would show differential associations with cognition and health. In the context of the second goal, we also compared the results obtained with the SHH-Q with those obtained with the FTP scale. Analyses were based on a subsample of BASE-II (see [22]).

Methods

Participants and Study Design

Participants ranged in age from 61 to 88 years ($n = 1,371$; mean = 70.1; SD = 3.78; 50.9% women), and were drawn from BASE-II [22]. None of the participants took medication that might affect memory function, and none had neurological disorders, psychiatric disorders, or a history of head injuries. All participants reported normal or corrected to normal vision, were right-handed, and scored over 27 on the Mini-Mental Status Examination [23]. Individuals participated in two cognitive testing sessions scheduled 1 week apart, and were tested in small groups (e.g. about 6 participants per group). Each session lasted about 3.5 h. From one session to the next, participants were asked to fill out psychosocial questionnaires related to subjective health and well-being. The medical exam consisted of a 2-day protocol including a comprehensive anamnesis performed by a physician and involving a wide array of laboratory and functional tests. The Ethics Committee of the Max Planck Institute for Human Development approved the cognitive battery and the psychosocial questionnaires, and the Ethics Committee of the Charité – Universitätsmedizin Berlin approved the medical examinations. Participants provided written informed consent and received monetary compensation for their participation.

Measures

Subjective Health Horizon Questionnaire

The original version of the SHH-Q consisted of 32 items and was administered in the first cognitive session (see online suppl. material, section 1; see www.karger.com/doi/10.1159/000441493 for all online suppl. material). After initial statistical analysis, two

items were removed because they showed high loadings across factors (see online suppl. material, section 2). The SHH-Q is designed to measure individual differences in the self-reported future time perspective on engaging with novelty and enriched environments as well as subjective appraisals of bodily health and physical mobility in terms of years left for those activities. In its final form, the SHH-Q consists of 30 items capturing four dimensions of subjective future time perspectives: (1) SHH-Q Novelty, which assesses novelty-oriented exploration (9 items); (2) SHH-Q Body, related to expectations regarding bodily fitness (9 items); (3) SHH-Q Work, related to occupational goals (5 items), and (4) SHH-Q Life Goals, asking about goals in life (3 items).

In addition, the SHH-Q contains four single items assessing life, independence, health, and disease expectancies, respectively, and one item assessing chronological age. A typical item from the SHH-Q Novelty subscale is, 'Up to what age do you think you will be physically and mentally able to meet new people?' The SHH-Q items are presented one by one on a computer screen, and are accompanied by a vector representation of the lifespan underneath, ranging from 10 years of age on the left to 110 years of age (see suppl. material, section 1). Prior to filling out the SHH-Q, a detailed and standardized verbal instruction was given to each participant. Participants were asked to respond to each item by shifting the mouse, whose position was set at their current chronological age, towards the maximum future age at which they estimated they would mentally and physically be able to perform the activity in question. Responses to items were adjusted by calculating the difference between individuals' actual age and their estimated future ages, and scaling by the ratio of actual age to maximum lifetime (defined as 110 years). The goal of this adjustment is to assign higher SHH-Q scores to older individuals reporting a difference between estimated age and chronological age that is identical to the difference reported by younger individuals. Specifically, the subjective time horizon is computed as the difference between estimated age and chronological age, multiplied by the ratio of current age over the assumed maximum age of 110 years. For instance, for a participant aged 75 years (chronological age) who responded to an item by moving the cursor to age 90 (estimated age), the time perspective would correspond to 15 years and would be scored as: $(75/110) \times (90-75) = 10.2$ age-adjusted years. In contrast, for a participant aged 65 years who responded to the same item by moving the cursor to age 80, thus providing the same time difference between estimated and chronological age of 15 years, the score on this item would be 8.86 age-adjusted years. The adjustment reflects the assumption that a time perspective of 15 years expressed at age 75 extends expected vitality into an older age than a time perspective of 15 years expressed at age 65. All analyses reported in this article are based on age-adjusted scores. We see it as a major strength of the SHH-Q that it provides subjective estimates in years rather than in an arbitrary metric (e.g. a Likert scale). We acknowledge that the SHH-Q items may serve as a resource for different types of analyses in addition to the age-adjusted scores used here.

Global Cognitive Functioning

The cognitive battery of BASE-II covers key cognitive abilities measured by 21 tasks (see for example [24]). Here, we focus on three main cognitive abilities: episodic memory (EM; Scene Encoding, Verbal Learning and Memory Test, Face-Profession task, Object Location task), working memory (WM; Spatial Updating,

Letter Updating, Number-N-Back), and fluid intelligence (Gf; Practical Problems, Figural Analogies, Letter Series). Furthermore, for each of the three ability domains, the chosen tasks varied in procedures and content, consisting of items that relate to verbal, numerical, or figural-spatial information (cf. online suppl. material, section 3).

The FTP Scale

We used the 10-item scale of the FTP [12], which was collected within the psychosocial assessment administered between the two cognitive sessions. Participants indicated the degree to which they agreed with an item on a Likert scale ranging from 1 (very untrue for me) to 7 (very true for me). The scale composite consists of the unit-weighted mean over all items, and lower scores indicate a limited future time horizon.

Objective Health Variables

We used two latent constructs indicating objective health, namely, physical fitness and metabolic functioning. Physical fitness represents one's state of general muscle strength, musculoskeletal capacity, and general vitality, and has been repeatedly indexed with grip strength and forced expiratory volume [25]. In this study, we used continuous information on grip strength and forced expiratory volume as indicators of physical fitness. Grip strength was measured with a dynamometer (Smedley, ranging from 0 to 100 kg). Participants started with the dominant followed by the nondominant hand, and were asked 'to grasp with as much force as possible'. Three measurements for each hand were taken, with the highest value of each hand being selected for later analysis. Forced expiratory volume in one second (FEV₁) was used as an overall indicator of lung function. We only analyzed spirometric measurements with sufficient measurement quality, fully in line with standard procedures. We would like to point out that other studies report around 30–50% data exclusion due to insufficient quality, following the guidelines of the American Thoracic Society (ATS; e.g. [26, 27]).

Metabolic health was defined as another construct in the domain of objective health. To define this construct, we combined a cluster of risk factors for cardiovascular disease and type 2 diabetes mellitus, which tend to cooccur due to overlapping etiology [28]. Metabolic risk factors have been shown to have implications on health-related, cognitive, neurobiological, social, and subjective well-being [29–33]. Specifically, metabolic status (MetS) was indexed by four continuous indicators, namely trunk fat, high-density lipoprotein (HDL), triglycerides and glucose serum concentrations, the latter three of which were ascertained by enzymatic assays (cobas HDL-C plus 3rd generation, cobas TG, and cobas GLUC2; Roche Diagnostics GmbH, Mannheim, Germany). Given that the associations between individual differences in MetS and cognition are not restricted to individuals who have been diagnosed with metabolic dysfunction, we see it as a strength of the present approach that our measure of MetS is dimensional rather than categorical and thus applicable to the entire sample (see [22]).

The SHH-Q and the FTP scale (among other psychosocial measures) were assessed in close temporal proximity to the cognitive assessments. In contrast, the objective health variables were collected about 1 year prior to cognitive testing (mean time difference in years = 1.2 years; SD = 0.80). To control for individual differences in time elapsing between measurements, we included the time interval as a control variable in the analyses.

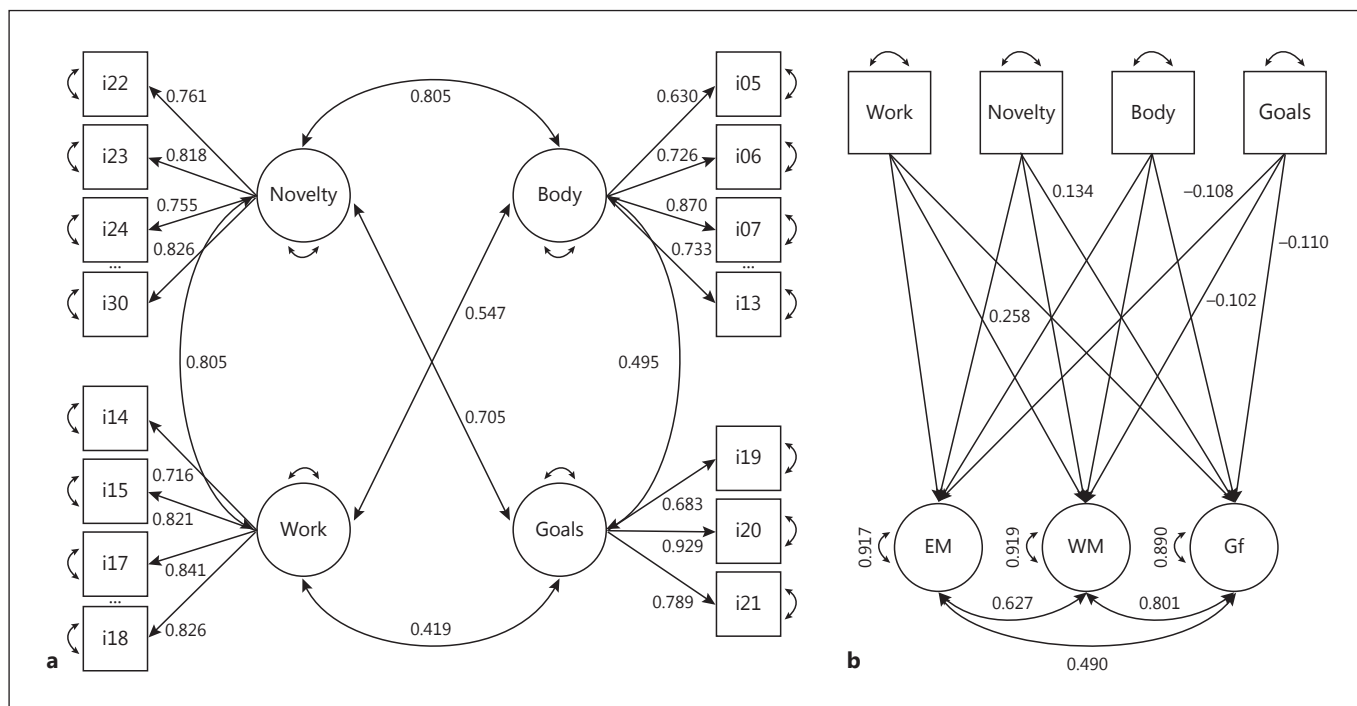


Fig. 1. a A simplified illustration of CFA results (model A). Four-factor solution of the SHH-Q providing best fit. Latent factor structure of the SHH-Q. Novelty and exploration perspective, Novelty (9 items); fitness perspective, Body (9 items); work-related perspective, Work (4 items); overall life goals and aims, Goals (3 items). Numbers next to single-headed arrows represent significant regression coefficients, and numbers next to double-headed arrows represent significant standardized correlations. **b** Model of

SHH-Q subscales regressed on cognitive abilities. Predictive validity of the SHH-Q for cognition. SHH-Q components are represented as unit-weighted composites (squares). Cognitive abilities are represented as latent factors (circles), and represent EM, WM, and Gf. Numbering of arrows as in **a**. Regression coefficients represent incremental predictions after statistical control for linear effects of age, education, and FTP scores. The indicators of the three cognitive ability factors are not shown.

Statistical Analyses

Data Preprocessing

Given our interest in individual variations of future time left, individual items on which participants responded below their actual age (resulting in a negative future time perspective) or individual items on which they responded at their actual age (zero future time perspective) were set to missing. Including these two types of responses, the proportion of missing responses for each item ranged from 2 to 9%. Moreover, when more than 10% of responses of a given individual were missing, suggesting that the participant did not comply with instructions, the case was deleted from the data set, resulting in deletion of 79 cases. For all analyses, missing data did not exceed 15.7% for most of the variables, except spirometric measurements where data needed to be excluded due to an insufficient level of quality (see Methods and online suppl. table 3).

Thus, when conducting SEM analyses, we used full information maximum likelihood (FIML). FIML yields unbiased parameter estimates and standard errors under the assumption that data are missing at random. The method minimizes the $-2 \log$ likelihood function for each individual based on the variables that are present, and, in this sense, makes optimal use of all available data.

(Robust) maximum likelihood estimation was used for parameter estimation, which assumes that data do not deviate substantially from a multivariate normal distribution¹. The measures of trunk fat, triglycerides, and HDL were log-transformed because they were skewed to the left.

Factorial Structure of the SHH-Q

Using Mplus v6.1 [34], we performed CFA to test the hypothesized four-factor structure of the SHH-Q. The initial model (model A) specified four intercorrelated latent variables, each with unique loadings from the corresponding SHH-Q items (fig. 1a). All items loaded reliably on the postulated latent factors (standardized loadings >0.500 , $p < 0.001$; online suppl. table 1; fig. 1a). In light of the substantial covariance between some of the four fac-

¹ The distribution of several items of the SHH-Q deviated reliably from normality. To test the robustness of the convergent and divergent validity of the models, we complemented our main analysis, based on untransformed data, by an analysis of transformed data using a multivariate Box-Cox transformation. The transformation did not change any of our main results. See section 3 in the supplementary material for further information.

tors, we compared the four-factor model with two three-factor models by imposing equality constraints on the Novelty and Body factors (model B), or on the Novelty and Work factors (model C), respectively (table 1a). We also tested the four-factor model against a one-factor model in which all of the latent variances and covariances were constrained to be equal (model D). For details regarding model comparisons and fit indices, see table 1a and section 5 of the supplementary material.

Associations of the SHH-Q with Cognition and Health, and Comparisons with the FTP Scale

We hypothesized that individuals' self-reports of their future novelty orientation would be associated with their current cognitive status, whereas self-reports of their future bodily fitness would be associated with their objective health. SEM was used to test these predictions. The cognitive domain was represented by the latent factors of EM, WM, and Gf (for further information, see section 3 of online suppl. material). Grip strength and FEV₁ were used to index physical fitness. Finally, based on earlier work [35], we defined a factor for MetS based on the variables of fasting blood glucose, triglycerides, HDL, and trunk fat. To establish the discriminant validity of the SHH-Q, we entered the FTP scale as a separate predictor in a stepwise regression by using SEM to assess how much variance is captured by the SHH-Q over and above the FTP scores. Variables were entered in the following order: first the covariates (age, education, and gender only for objective health), second the FTP, and third the four SHH-Q scores as predictors. We set up three different series of stepwise latent regression models testing three separate outcome measures on the latent level: (a) cognition models, in which cognition was represented by three intercorrelated latent factors, EM, WM, and Gf; (b) MetS models, and (c) physical fitness models. To allow unbiased comparisons between SHH-Q scores and FTP scores in this set of analyses, the four SHH-Q components were represented by unit-weighted composite scores, rather than as latent factors.

Results

Sample Characteristics

Descriptive statistics of the main variables and their correlations are provided in section 6 of the supplementary material and supplementary tables 3 and 4. There were no gender differences except for three of the objective health variables (FEV₁, grip strength, trunk fat; higher in males, $p < 0.001$). Age and years of education were correlated with most variables. The mean score of the FTP scale was 2.5 (SD = 0.7). Objective health values and psychological measures were comparable with previous reports for healthy adults in this age range.

Factorial Structure of the SHH-Q

Core results of the confirmatory factor analyses for the four-factor model A are shown in figure 1a. Model A provided the best fit to the data [$\chi^2_{293} = 1,050.8$, comparative fit index (CFI) = 0.94, root mean square error of approximation (RMSEA) = 0.045, 90% CI 0.042–0.046, stan-

dardized root mean square residual (SRMR) = 0.041; see also table 1], relative to the two three-factor models (model B: $\chi^2_{295} = 2,050.5$, CFI = 0.87, RMSEA = 0.068, 90% CI 0.065–0.070, SRMR = 0.058; model C: $\chi^2_{295} = 1,509.1$, CFI = 0.90, RMSEA = 0.051, 90% CI = 0.048–0.054, SRMR = 0.056) and to the one-factor model (model D: $\chi^2_{325} = 3,573.3$, CFI = 0.75, RMSEA = 0.092, 90% CI 0.089–0.094, SRMR = 0.077).

Associations with Cognition and Health Cognition

Three latent regression models were set up to examine simultaneous associations of the four SHH-Q dimensions with latent factors of WM, EM, and Gf, which were defined as correlated dependent variables. For each cognitive ability, the FTP score and then the four SHH-Q composite scores were entered as manifest predictor variables after covariates (age and years of education) were taken into account. For EM, the SHH-Q accounted for a reliable amount of variance after controlling for age, years of education, and the FTP score (R^2 change = 0.047; see table 1b, cognitive model). Inspection of path coefficients indicated that this association was due to the Novelty dimension of the SHH-Q ($\beta = 0.258$, standard error = 0.050; $p < 0.001$; fig. 1b).

Health

Two separate latent stepwise regression models were set up to examine the simultaneous associations of the four SHH-Q dimensions with latent factors of physical fitness and MetS, respectively, controlling for age, years of education, time difference between health and SHH-Q assessments, and the FTP. For physical fitness, the SHH-Q did not account for a reliable amount of additional variance (R^2 change = 0.001, $p > 0.05$; table 1b). In contrast, the SHH-Q was associated with reliable amounts of variance in MetS after controlling for age, years of education, and the FTP scale (R^2 change = 0.045, $p < 0.001$; table 1). Inspection of path coefficients revealed a positive association of the SHH-Q Body dimension, and a negative association of the SHH-Q Novelty dimension with MetS (table 1b).

Discriminant Validity: Comparisons with the FTP Scale

The FTP was reliably associated with each of the four dimensions of the SHH-Q composite scores: Novelty, $r = 0.36$; Body, $r = 0.39$; Work, $r = 0.28$; Life Goals, $r = 0.27$ (see online suppl. table 4).

When entering the FTP scale as a separate variable into our stepwise regression models and then together with the four SHH-Q composite scores, the results

Table 1. Confirmatory factor analyses and factorial validity of SHH-Q**a** CFA testing factorial validity of four-factor solution of the SHH-Q

Model	χ^2	d.f.	p	CFI	RMSEA/90% CI	SRMR	χ^2 of model A vs. models B–D/d.f./p
A	1,050.828	293	<0.001	0.943	0.045/0.042–0.048	0.041	
B	2,050.504	295	<0.001	0.867	0.068/0.065–0.071	0.058	2,162.33/2/<0.001
C	1,509.113	295	<0.001	0.908	0.056/0.054–0.059	0.051	181.05/2/<0.001
D	3,573.317	325	<0.001	0.752	0.092/0.089–0.095	0.077	1,586.08/6/<0.001

CFA = Confirmatory factor analyses; CFI = comparative fit index; RMSEA = root mean square error of approximation; CI = confidence interval; model A = four-factor model; models B and C = three-factor models; model D = single-factor model.

b Predictive validity of FTP and SHH-Q factors for cognition and objective health

Dependent variables	Predictors	Coefficients	SE	p	R ² /R ² change	Incremental validity ^{a, b} , χ^2 /d.f./p
<i>Stepwise latent regression models for cognition</i>						
EM	1 Age	–0.138*	0.048	0.008		
	Education	0.257*	0.042	<0.001	0.094	
	2 FTP	–0.052	0.046	0.260	0.094/0.000	2.9/3/0.398
	3 SHH-Q Novelty	0.258*	0.050	<0.001	0.141/0.047	45.6/12/0.000*
	SHH-Q Body	–0.037	0.062	0.551		
	SHH-Q Work	0.047	0.062	0.449		
	SHH-Q Life Goals	–0.108*	0.051	0.027		
WM	1 Age	–0.128*	0.041	<0.001		
	Education	0.309*	0.036	<0.001	0.126	
	2 FTP	–0.074	0.043	0.207	0.126/0.000	2.9/3/0.398
	3 SHH-Q Novelty	0.075	0.069	0.274	0.140/0.014	45.6/12/0.000*
	SHH-Q Body	0.043	0.058	0.458		
	SHH-Q Work	0.054	0.061	0.376		
	SHH-Q Life Goals	–0.102*	0.046	0.027		
Gf	1 Age	–0.138*	0.040	<0.001		
	Education	0.346*	0.035	<0.001	0.162	
	2 FTP	–0.098*	0.042	0.020	0.162/0.000	2.9/3/0.398
	3 SHH-Q Novelty	0.134*	0.061	0.022	0.190/0.028	45.6/12/0.000*
	SHH-Q Body	0.000	0.057	0.998		
	SHH-Q Work	0.112	0.058	0.055		
	SHH-Q Life Goals	–0.110*	0.043	0.010		
<i>Stepwise latent regression models for physical fitness</i>						
Fitness	1 Age	–0.084*	0.025	<0.001		
	Education	0.005	0.022	0.464		
	Gender	–0.810*	0.013	<0.001	0.854	
	2 FTP	0.038	0.024	0.994	0.854/0.000	0.2/1/0.616
	3 SHH-Q Novelty	0.058	0.043	0.145	0.856/0.002	0.2/1/0.616
	SHH-Q Body	0.030	0.041	0.564		
	SHH-Q Work	–0.020	0.038	0.563		
	SHH-Q Life Goals	–0.006	0.028	0.820		

Table 1 (continued)

Dependent variables	Predictors	Coefficients	SE	p	R ² /R ² change	Incremental validity ^{a, b} , χ^2 /d.f./p
<i>Stepwise latent regression models for MetS</i>						
MetS	1 Age	-0.085*	0.038	0.024		
	Education	-0.080*	0.038	0.036		
	Gender	-0.339*	0.051	<0.001	0.250	
	2 FTP	-0.077*	0.039	0.047	0.251/0.001	2.9/3/0.398
	3 SHH-Q Novelty	0.199*	0.060	0.001	0.296/0.045	17.7/4/0.001*
	SHH-Q Body	-0.230*	0.056	<0.001		
	SHH-Q Work	0.034	0.058	0.579		
	SHH-Q Life Goals	-0.021	0.040	0.608		

Stepwise regression model for three outcome measures: cognition, fitness, and metabolic status (MetS). Each model shows the final results after a series of three stepwise regression models including (1) covariates: age, education, and gender, (2) the Future Time Perspective (FTP) score, and (3) all four SHH-Q composite scores. * $p < 0.05$, significant difference. ^a Incremental validity is used to determine whether entering FTP first and SHH-Q second increases the predictive ability of the dependent variables of each model by applying a χ^2 difference test. ^b Incremental validity values are equal for all three cognitive factors because they are based on the same model. SE = Standard error; χ^2 = Chi-square statistics; d.f. = degrees of freedom; p = probability value.

demonstrated that significant variance is captured only by the SHH-Q itself over and above the FTP scores (table 1b). In contrast, the FTP scale did not show reliable associations with any of the cognitive or health-related factors, and did not predict any additional variance in these constructs beyond the SHH-Q (table 1b).

Discussion

The purpose of this study was to introduce the SHH-Q as a new self-report measure of future time perspectives pertaining to specific aspects of an active lifestyle. We were able to validate that the SHH-Q consists of four correlated but distinct subscales: Novelty, Body, Work, and Life Goals. The superior fit of the four-factor model relative to three-factor and one-factor models shows that these four subscales constitute distinct dimensions of future time perspectives.

The FTP scale correlated moderately with each of the four dimensions of the SHH-Q. However, in contrast to the SHH-Q, the FTP scale did not show any statistically reliable associations with objective measures of cognition or somatic health. This finding underscores the superior content validity of the SHH-Q as a novel instrument for assessing individuals' time perspectives on being physically fit and cognitively active in the future.

The SHH-Q items related to novelty versus bodily fitness formed two separate subscales, and these subscales

showed differential associations with objective measures of memory and health. Specifically, SEM regression analyses revealed that higher scores on the SHH-Q Novelty dimension were associated with higher EM performance, whereas higher scores on the SHH-Q Body dimension were associated with better MetS. Thus, the self-perceived time perspectives on being cognitively and physically active show domain-specific, selective associations with concurrently assessed markers of cognition and health. Clearly, a unidimensional omnibus measure of future time perspective such as the FTP is not well suited to capture these differential associations.

The association between the Novelty dimension of future time perspectives and EM functioning is conceptually important, given that EM contributes to exploring novel environments (e.g. [36–39]). This association certainly merits further investigation at behavioral and neural levels of analysis. In neural terms, the goal-directed and motivated exploration of environments is assumed to depend on brain circuitry that includes medial temporal structures, such as the hippocampus, and also the basal ganglia [6–8, 40–43]. Several components of this network show age-related decline in normal aging [44–47], and we would like to propose that this decline might narrow the subjective experience of future time horizons. Obviously, structural and functional brain imaging data are needed to corroborate this claim. One prediction emanating from our line of reasoning is that the Novelty dimension of the SHH-Q is related to the functional and structural

integrity of brain regions that support the encoding of novel information into EM.

Unlike SHH-Q Novelty, the SHH-Q Body dimension showed unique associations with metabolic health status. This correlational dissociation suggests that imagining oneself exploring novel environments may differ in important ways from imagining oneself as being physically active. Physical activity can be carried out in a familiar environment; hence, its future time perspective may be more strongly rooted in current bodily health than in the ability to simulate the future. Exploring these differences in neural and somatic correlates in greater detail is an important avenue for future research.

Limitations

The present study has a number of limitations. First and foremost, its results are based on cross-sectional observations that do not provide direct information about individual differences in change. Second, the discriminant validity of the Work and Life Goals subscales remains to be examined more closely in future analyses. Specifically, the lack of significant associations of the Work and Life Goals subscales with measures of health and cognition requires further investigation, and the putative associations of these two subscales with socioeconomic and social factors, which were not fully explored in the present study, need to be examined in greater detail.

Third, for practical reasons, the health variables included in the present study had all been collected more than a year before the cognitive assessment and administration of the SHH-Q took place. It is likely that this time lag reduced the strength of associations between the SHH-Q subscales and the factors of somatic health.

Fourth, psychological research has shown that future time perspectives are closely linked to individual differences in motivation and goal pursuit (e.g. [25, 48, 49]). These associations, which would help to get a better sense of the psychological mechanisms involved in responding to SHH-Q items, need to be examined more carefully in future work.

In the present analyses, responses to SHH-Q items that implied a zero or negative time perspective were set to missing, primarily to avoid a bimodal distribution of response scores at the item level. However, such responses may be of interest in their own right, given that the respondent may express the view that the time horizon for the activity in question is about to end right now (i.e. a zero score) or has expired a number of years ago (i.e. a negative score). Relating these responses to motivational variables may help to shed light on this issue.

Finally, it needs to be kept in mind that BASE-II involves a convenience sample [22]. As a partial remedy to this limitation, BASE-II has been linked to data from the German Socio-Economic Panel (SOEP), which uses a far more representative sampling scheme than BASE-II. Systematic comparisons of BASE-II data with SOEP data allow for estimates of selection bias, and offer statistical tools for bias correction. As research with the SHH-Q unfolds in the context of BASE-II and in other studies, issues of selective sampling, replicability, and generalizability need to be addressed.

Conclusion

The results of the present study indicate that the future time perspectives of older adults are not unidimensional. Instead, people differ in the expected temporal extension of activities related to novelty, bodily fitness, occupational goals as well as overall goals in life. The SHH-Q captures these four dimensions of individuals' future time perspective in a psychometrically valid manner. Future research needs to explore the links of each of these four facets of future time perspective to behavior, specific aspects of brain integrity, and bodily health, and the differential modulation of these links by socioeconomic factors. In particular, longitudinal observations and experimental interventions are needed to probe the psychological mechanisms underlying the construction of future time perspectives, and the embedding of these mechanisms into biological and social systems of influence.

Acknowledgements

We are grateful for the assistance of the IT team at the Max Planck Institute for Human Development (Thomas Feg, Sebastian Schröder, and Berndt Wischniewski), to Kirsten Becker for research assistance, and to the telephone studio (Gabi Jedidi-Zerm and Sabrina Strehlow). Thanks are due to Julia Delius for editorial assistance. The first author thanks the Marie-Luise und Ernst Becker Stiftung for initial support of the development of the SHH-Q.

This article reports data from the BASE-II research project, which is supported by the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF). Another source of funding is the Max Planck Institute for Human Development, Berlin, Germany. Additional contributions (e.g. equipment, logistics, and personnel) are made from each of the other participating sites. Further details about the study can be obtained at <https://www.base2.mpg.de/en>.

References

- Rowe JW, Kahn RL: Successful aging 2.0: conceptual expansions for the 21st century. *J Gerontol B Psychol Sci Soc Sci* 2015;70:593–596.
- Hötting K, Holzschneider K, Stenzel A, Wolbers T, Röder B: Effects of a cognitive training on spatial learning and associated functional brain activations. *BMC Neurosci* 2013;14:73.
- Maass A, Düzel S, Goerke M, Becke A, Sobieray U, Neumann K, et al: Vascular hippocampal plasticity after aerobic exercise in older adults. *Mol Psychiatry* 2015;20:585–593.
- Nagamatsu LS, Flicker L, Kramer AF, Voss MW, Erickson KI, Hsu CL, et al: Exercise is medicine, for the body and the brain. *Br J Sports Med* 2014;48:943–944.
- Lövdén M, Wenger E, Mårtensson J, Lindenberg U, Bäckman L: Structural brain plasticity in adult learning and development. *Neurosci Biobehav Rev* 2013;37:2296–2310.
- Nithianantharajah J, Hannan AJ: Enriched environments, experience-dependent plasticity and disorders of the nervous system. *Nat Rev Neurosci* 2006;7:697–709.
- van Praag H, Kempermann G, Gage FH: Neural consequences of environmental enrichment. *Nat Rev Neurosci* 2001;1:191–198.
- Düzel E, Bunzeck N, Guitart-Masip M, Düzel S: Novelty-related motivation of anticipation and exploration by dopamine (NOMAD): implications for healthy aging. *Neurosci Biobehav Rev* 2010;34:660–669.
- Lindenberg U: Human cognitive aging: cor-riger la fortune? *Science* 2014;346:572–578.
- Brandtstädter J, Rothermund K, Kranz D, Kühn W: Final decenterations – personal goals, rationality perspectives, and the awareness of life's finitude. *Eur Psychol* 2010;15:152–163.
- Brandtstädter J, Rothermund K: The life-course dynamics of goal pursuit and goal adjustment: a two-process framework. *Dev Rev* 2002;22:117–150.
- Carstensen L, Lang FR: Future Time Perspective Scale. Stanford, Stanford University, 1996.
- Lang FR, Carstensen L: Time counts: future time perspective, goals, and social relationships. *Psychol Aging* 2002;17:125–139.
- Kozik P, Hoppmann CA, Gerstorf D: Future time perspective: opportunities and limitations are differentially associated with subjective well-being and hair cortisol concentration. *Gerontology* 2015;61:166–174.
- Mather M, Carstensen LL: Aging and motivated cognition: the positivity effect in attention and memory. *Trends Cogn Sci* 2005;9:496–502.
- Mather M, Schoeke A: Positive outcomes enhance incidental learning for both younger and older adults. *Front Neurosci* 2011;5:129.
- Gruber MJ, Gelman BD, Ranganath C: States of curiosity modulate hippocampus-dependent learning via the dopaminergic circuit. *Neuron* 2014;84:486–496.
- Lisman J, Grace AA, Duzel E: A neoHebbian framework for episodic memory; role of dopamine-dependent late LTP. *Trends Neurosci* 2011;34:536–547.
- Lisman JE, Grace AA: The hippocampal-VTA loop: controlling the entry of information into long-term memory. *Neuron* 2005;46:703–713.
- Bollen KA: Structural Equations with Latent Variables. New York, Wiley, 1989.
- McCardle J, Prescott Carol A: Age-based construct validation using structural equation modeling. *Exp Aging Res* 1992;18:87–115.
- Bertram L, Böckenhoff A, Demuth I, Düzel S, Eckardt R, Li S-C, et al: Cohort profile: The Berlin Aging Study II (BASE-II). *Int J Epidemiol* 2014;43:703–712.
- Folstein MF, Robins LN, Helzer JE: The Mini-Mental State Examination. *Arch Gen Psychiatry* 1983;40:812.
- Schmiedek F, Lövdén M, Lindenberg U: Hundred days of cognitive training enhance broad cognitive abilities in adulthood: findings from the COGITO study. *Front Aging Neurosci* 2010;2:27.
- Infurna FJ, Gerstorf D: Linking perceived control, physical activity, and biological health to memory change. *Psychol Aging* 2013;28:1147–1163.
- Szanto O, Montnery P, Elmstahl S: Prevalence of airway obstruction in the elderly: results from a cross-sectional spirometric study of nine age cohorts between the ages of 60 and 93 years. *Prim Care Respir J* 2010;19:231–236.
- Hill K, Goldstein RS, Guyatt GH, Blouin M, Tan WC, Davis LL, et al: Prevalence and underdiagnosis of chronic obstructive pulmonary disease among patients at risk in primary care. *CMAJ* 2010;182:673–678.
- Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al: Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation* 2009;120:1640–1645.
- Yaffe K: Metabolic syndrome and cognitive disorders: is the sum greater than its parts? *Alzheimer Dis Assoc Disord* 2007;21:167–171.
- Barnes DE, Yaffe K: The projected effect of risk factor reduction on Alzheimer's disease prevalence. *Lancet Neurol* 2011;10:819–828.
- Raz N: Diabetes: brain, mind, insulin – what is normal and do we need to know? *Nat Rev Endocrinol* 2011;7:636–637.
- Bender AR, Daugherty AM, Raz N: Vascular risk moderates associations between hippocampal subfield volumes and memory. *J Cogn Neurosci* 2013;25:1851–1862.
- Netz Y, Wu M-J, Becker BJ, Tenenbaum G: Physical activity and psychological well-being in advanced age: a meta-analysis of intervention studies. *Psychol Aging* 2005;20:272–284.
- Muthén LK, Muthén BO: Mplus User's Guide. Los Angeles, Muthén & Muthén, 2010.
- Watts AS, Loskutova N, Burns JM, Johnson DK: Metabolic syndrome and cognitive decline in early Alzheimer's disease and healthy older adults. *J Alzheimers Dis* 2013;35:253–265.
- Hassabis D, Maguire EA: Deconstructing episodic memory with construction. *Trends Cogn Sci* 2007;11:299–306.
- Wheeler MA, Stuss DT, Tulving E: Toward a theory of episodic memory: the frontal lobes and autonoetic consciousness. *Psychol Bull* 1997;121:331–354.
- Habib R, McIntosh AR, Wheeler MA, Tulving E: Memory encoding and hippocampally-based novelty/familiarity discrimination networks. *Neuropsychologia* 2003;41:271–279.
- Bird CM, Burgess N: The hippocampus and memory: insights from spatial processing. *Nat Rev Neurosci* 2008;9:182–194.
- Lövdén M, Schaefer S, Noack H, Bodammer NC, Kühn S, Heinze H-J, et al: Spatial navigation training protects the hippocampus against age-related changes during early and late adulthood. *Neurobiol Aging* 2012;33:620.e9–620.e22.
- Nyberg L, Lövdén M, Riklund K, Lindenberg U, Bäckman L: Memory aging and brain maintenance. *Trends Cogn Sci* 2012;16:292–305.
- Maguire EA, Burgess N, Donnett JG, Frackowiak RS, Frith CD, O'Keefe J: Knowing where and getting there: a human navigation network. *Science* 1998;280:921–924.
- Curlik DM, Maeng LY, Agarwal PR, Shors TJ: Physical skill training increases the number of surviving new cells in the adult hippocampus. *PLoS One* 2013;8:e55850.
- Rodrigue KM, Haacke EM, Raz N: Differential effects of age and history of hypertension on regional brain volumes and iron. *Neuroimage* 2011;54:750–759.
- Raz N, Lindenberg U: Life-span plasticity of the brain and cognition: from questions to evidence and back. *Neurosci Biobehav Rev* 2013;37:2195–2200.
- Hedden T, Gabrieli JD: Healthy and pathological processes in adult development: new evidence from neuroimaging of the aging brain. *Curr Opin Neurol* 2005;18:740–747.
- Raz N: Decline and compensation in aging brain and cognition: promises and constraints. Preface. *Neuropsychol Rev* 2009;19:411–414.
- Lachman ME, Agrigoroaei S: Promoting functional health in midlife and old age: long-term protective effects of control beliefs, social support, and physical exercise. *PLoS One* 2010;5:e13297.
- Heckhausen J, Wrosch C, Schulz R: A motivational theory of life-span development. *Psychol Rev* 2010;117:32–60.